CLAIMS

What is claimed is:

1. A method for encoding a specified neural system into a representative genome, wherein the neural system comprises an array of interconnected neurons and each neuron has an input and an output, said method comprising the steps of:

for a given neuron, encoding a specification of the conversion of neuron input to neuron output by a processing gene corresponding to the given neuron;

encoding the connections from the given neuron by one or more connection genes, each corresponding to the given neuron; and

selectively ordering the processing genes and connection genes corresponding to respective neurons of the neural system to form said genome.

2. The method of Claim 1, wherein:

said genome includes different types of processing genes and further includes different types of connection genes, each type of processing gene encoding a different type of neuron, and each type of connection gene encoding a different type of interaction between neurons.

3. The method of Claim 2, wherein:

a processing gene encodes a neural output function for its corresponding neuron, wherein the encoded neural output function provides neuron output as a specified function of collective neuron inputs.

4. The method of Claim 3, wherein:

a neural output function encoded in a processing gene is encoded in the form of a mathematical expression tree having internal nodes and leaf nodes, said internal nodes representing a set of mathematical operators, and said leaf nodes representing a set of terminal inputs to said mathematical expression tree.

5. The method of Claim 2, wherein:

said method includes the step of performing mutation operations on selected processing genes and selected connection genes.

6. The method of Claim 5, wherein:

a group of genes of said genome can be exchanged with a group of genes of another genome that likewise comprises processing genes and connection genes.

7. The method of Claim 2, wherein:

each of said connection genes encodes the location of a neuron connection to another neuron, and further encodes a weight associated with the connection.

8. The method of Claim 7, wherein:

each of said connection genes can be mutated.

9. The method of Claim 3, wherein:

each of said connection genes is subdivided into a specified number of components, each component comprising a functional capability.

10. The method of Claim 9, wherein;

one of said components comprises a strength sub-gene encoding a weight function that determines the weight of a corresponding connection.

11. The method of Claim 10, wherein:

said strength sub-gene is represented by a mathematical expression tree having an associated set of operators.

12. The method of Claim 11, wherein:

at least one of said operator sets includes one or more operators for enabling the neural system to reconfigure its neuron connections.

13. The method of Claim 12, wherein:

said operators for reconfiguring connections comprise a first operator for creating new neuron connections, and a second operator for removing neurons and neuron connections.

14. The method of Claim 13, wherein:

a first operator in a processing gene selectively directs a neuron to make one new connection for each one of its connection types, and a first operator in a strength sub-gene selectively directs a neuron to make a new connection only of that sub-gene's type.

15. The method of Claim 13, wherein:

a second operator in a processing gene removes neurons and connections from the neural system, and a second operator in a strength sub-gene removes only that sub-gene's connection.

16. The method of Claim 2, wherein:

each of said connection genes includes a plurality of parameter sub-genes, each parameter sub-gene disposed to encode either a specified value, or a mathematical expression tree, selectively.

17. The method of Claim 16, wherein:

one of said parameter sub-genes comprises a count sub-gene, said count sub-gene specifying the number of connections of each type made by each type of neuron.

18. The method of Claim 16, wherein:

said parameter sub-genes include direction and range sub-genes that collectively determine where each connection to a neuron goes.

19. The method of Claim 16, wherein:

one of said parameter sub-genes comprises a target sub-gene indicating the kinds of neurons that respective connections are to link with.

20. The method of Claim 16, wherein:

said method includes the step of mutating said sub-genes, selectively, of said connection genes.

21. The method of Claim 11, wherein:

a processing gene and a strength sub-gene each encodes an output function having a specified form and corresponding inputs, at least one of said output functions being responsive to positive reinforcement and negative reinforcement signals applied to its corresponding inputs for use in selectively training said neural system.

22. A method for building a neural system for use in a specified application, said method comprising the steps of:

encoding a genome to represent one or more types of neurons in an array, and to further represent one or more types of interactions between said neurons;

inserting said neurons encoded in said genome into said neural system as input neurons, the initial number of said input neurons being determined at least in part by said application;

selectively building connections between respective input neurons; and

selectively creating new neurons.

23. The method of Claim 22, wherein:

each neuron represented by said genome has a neural output function encoded by a processing gene, wherein different types of neurons are respectively encoded by different types of processing genes; and

each of said interactions between neurons is encoded by a connection gene, wherein different types of interactions are respectively encoded by different types of connection genes.

24. The method of Claim 22, wherein:

said encoded representation of one or more types of interactions between said neurons specifies the number of connections to build, determines a target area in which a connection is to be made, and indicates the type of neuron that a connection is to be made to.

25. The method of Claim 24, wherein building a neuron connection comprises:

selecting a first location within a specified target area;

forming a connection with a neuron found at said first location, if the found neuron is of a specified type;

selecting a second location to search for a neuron, if a neuron found at said first location is not of said specified type; and

creating a neuron of said specified type at said first location, if no neuron can be found at said first location.

26. The method of Claim 25, wherein:

said encoded representation of said interaction between said neurons selectively specifies one or more conditions selected from a group, said group including the conditions that a neuron of said specified type is created only if a pre-existing neuron of said specified type cannot be found anywhere in said specified target area; a connection to a pre-existing neuron of said specified type is made only if empty spaces in which to create new neurons cannot be found anywhere in said specified target area; creation of new neurons is not allowed; and connections to pre-existing neurons are not allowed.

27. The method of Claim 26, wherein:

creation of a new neuron requires creation of one or more new connections therefor, said new connections either linking to previously existing neurons or creating new post-synaptic neurons; and

said connection creation process continues until every new connection is either made to a previously existing neuron, or a pre-set limit on the maximum number of neurons in the neural system is reached.

28. The method of Claim 27, wherein:

upon completion of said neural system, a set of the last neurons to be created are designated as output neurons.

29. The method of Claim 28, wherein:

said neural system contains a substantial number of different circuitry combinations.

30. The method of Claim 29, wherein:

said neural system comprises an array having a specified number of dimensions.

31. A method for developing a neural system adapted to perform a specified task, said method comprising the steps of:

selecting a population of neural systems, each neural system comprising an array of interconnected neurons;

encoding each neural system into a representative genome, wherein the genome for a given neural system encodes a neural output function for each neuron in a corresponding processing gene, and encodes the connections from each neuron in one or more corresponding connection genes, each connection gene including a weight function;

operating said given neural system to perform said specified task during a trial period;

continually monitoring performance of said given neural system during said trial period;

applying reinforcement signals determined from said continually monitored performance as inputs to the neural output function of each processing gene of said given neural system, and also as inputs to the weight function of each connection gene thereof; and

determining the fitness of said given neural system for performing said specified task after the conclusion of said trial period.

32. The method of Claim 31, wherein:

said reinforcement signals include a positive reinforcement signal PR_t and a negative reinforcement signal NR_t received at a time step t included in a total number of time steps T.

33. The method of Claim 32, wherein:

the fitness F of said given neural system for performing said specified task is determined from the relationship. $$F = \sum_{t \in 0..T} (PR_t - NR_t).$$

34. The method of Claim 33, wherein:

a set of said genomes, respectively representing the neural systems of said population determined to have the highest fitness values, are selected for use in forming a new generation of neural systems.

35. The method of Claim 33, wherein each genome is subjected to a succession of selection trials, and is periodically tested to detect loss of previous adaptations.

36. The method of Claim 35, wherein:

each of said selection trials is disposed to develop characteristics associated with intelligence.

37. A computer system for encoding a specified neural system into a representative genome, wherein the neural system comprises an array of interconnected neurons and each neuron has an input and an output, said computer system comprising:

one or more processors; and

a computer readable medium connected to the processors, said computer readable medium including processor instructions configured to be read by said processors and thereby cause said processors to:

for a given neuron, encode a specification of the conversion of neuron input to neuron output by a processing gene corresponding to the given neuron;

encode the connections from the given neuron by one or more connection genes, each corresponding to the given neuron; and

selectively order the processing gene and connection gene corresponding to respective neurons of the neural system to form said genome.

38. The computer system of Claim 37, wherein:

said genome includes different types of processing genes and further includes different types of connection genes, each type of processing gene encoding a different type of neuron, and each type of connection gene encoding a different type of interaction between neurons.

39. The computer system of Claim 38, wherein:

a processing gene encodes a neural output function for its corresponding neuron, wherein the encoded neural output function provides neuron output as a specified function of collective neuron inputs.

40. The computer system of Claim 38, wherein:

said method includes the step of performing mutation operations on selected processing genes and selected connection genes.